DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Bachelor's Thesis in Informatics: Games Engineering

# Adaptive Difficulty in Massively Multiplayer Online Role-Playing Games to Create Optimal Experience

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# Adaptive Schwierigkeit in Massen-Mehrspieler-Online-Rollenspielen zur Schaffung optimaler Erfahrungen

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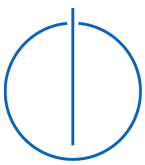

I confirm that this bachelor's thesis in informatics: games engineering is my own work and I have documented all sources and material used.

# Acknowledgments

# Abstract

The objective of this paper is to investigate the approach of using adaptive difficulty in Massively Multiplayer Online Role-Playing Games (MMORPG) to help create an optimal game experience for the player. By analyzing how a boss fight works in an MMORPG, measurable parameters are identified to determine whether difficulty adjustments would enhance the player's game experience. Furthermore, elements of the system are established which can be regulated in order to apply difficulty adjustments. These findings are in turn implemented in a small scale project to simulate a boss fight with difficulty adjustments and evaluated afterwards.
The results propose that small dynamic appropriate changes to the difficulty can effectively improve the experience of the game. However, accurately determining when and how to change the difficulty is a complex endeavor especially in MMORPGs. An adaptive difficulty system can prove useful for a better game experience in an MMORPG but has to be properly balanced with other factors like community.

# Contents

# 1 Introduction

## 1.1 Motivation

In the wake of the COVID-19 pandemic, more and more people spent time indoors due to lock-down restrictions or following social distancing rules. As a means to fulfill social needs, meetings and gatherings moved to online platforms and consequently these online platforms became increasingly popular in the general public. Among those online platforms are online multiplayer video games. According to a survey, 60% of 4579 respondents stated that they played more multiplayer video games in the pandemic than before [Cle21]. This also gave rise to a particular video game genre that combines a large amount of people with social aspects and role-play: MMORPGs.
I picked up *Final Fantasy XIV* [Eni10], an MMORPG, last year and it gave me a means to keep socializing and meet new people while also engaging with an immersive world and giving me a fun game experience. As someone who plays plenty of video games, game mechanics and rules in *Final Fantasy XIV* felt intuitive to me and easy to pick up. The same can not be said for someone who has never played video games before but decided to also pick up *Final Fantasy XIV*. The game might prove too hard for someone like that or too easy for someone who is more affinitive to video games in general. Nevertheless, in an MMORPG both of these kinds of players might end up in a group together and take part in the same content. How should one balance a game where not only the game is faced with a variety of players with different skill levels and knowledge who will also engage with the same content simultaneously? Is it possible to adjust the difficulty dynamically depending on what kind of players are engaging with a piece of content? One of the answers to this problem is called "Adaptive Difficulty" which I will thoroughly examine in this paper.

## 1.2 Problem Statement

In order to investigate these questions, it is necessary to pin down the problem at hand and express the objective of this paper. With adaptive difficulty in mind, the goal can be narrowed down to what game elements in an MMORPG can be used to extract information so that the difficulty can be appropriately adjusted if needed.

Furthermore, using this information game elements will be identified that allows for appropriate change in the difficulty. Ultimately, the goal of this paper is to create an optimal experience for all players. Thus, identifying both the information and the tools to implement adaptive difficulty in an effort to improve the game experience is essential. As a result, the problem can be formulated as follows: What information and tools are useful or needed in order to facilitate adaptive difficulty in an effort to create an optimal experience?

With that said, narrowing down the scope of this paper is important as adapting the difficulty for an MMORPG as a whole is too big for the purpose of this paper. I will focus on boss fights since those are commonly shared among the genre in one form or another. Overcoming a challenge or enemy together as a group of players is a common element in most MMORPGs which can easily suffer from balancing issues. To that end, finding a base for implementing adaptive difficulty in the framework of a boss fight will aid in improving the overall game experience.

## 1.3 Methodology

First of all it is necessary to define what constitutes good game experience, especially in the context of an MMORPG. To create a good game experience we need to understand the influences on a game experience and the psychology behind it for the player. Additionally, in the context of MMORPGs it is essential to identify the key features of an MMORPG. Understanding the game genre will give insight in how much exactly difficulty adjustment impacts the game as a whole and consequently also influence the game experience.
After that, flow will be introduced as another concept since it presents an important correlation between difficulty and player enjoyment. The influence on the game experience will be examined and how that concept can be applied to adaptive difficulty. On top of that, the definitions of both predetermined difficulty and adaptive difficulty are necessary to decide what aspects are useful to make the game experience as good as possible. As predetermined difficulty is most commonly used throughout video game history, it would make sense to look into its benefits and applications. Adding to that, definition and known concepts of adaptive difficulty will be introduced and studied. In that regard, I will also introduce the notion of optimal difficulty with both these definitions in mind and in the context of an MMORPG. The notion of optimal difficulty in connection with MMORPGs is key in answering the questions of this paper.
Following this, I will use the acquired knowledge and thoroughly examine a boss fight in *Final Fantasy XIV*. As there is no recipe in how to make a good MMORPG, or any

game in that regard, evaluating a single boss fight implementation of one game will not be meaningful for the genre at large. However, general features of a boss fight can be extracted and abstracted and thus give us insight into how and where a boss fight can be adjusted to achieve a better experience.
Afterwards, using all the previous findings I implement a prototype adaptive difficulty adjustment system and evaluate its effectiveness and impact on the game experience. For this, I use an open source project called *Boss Room* programmed in Unity which is not an MMORPG but it is a small multiplayer-compatible RPG with a boss fight which suffices for the extent of this paper. I will then discuss the results of this implementation in its strengths and flaws and possible improvements.

# 2 Game Experience

## 2.1 The MMORPG genre

Before diving into what makes an MMORPG "fun" and "good", we need to first understand what an MMORPG is and what its main features are. As one can determine from its name, it is a large scale role-playing multiplayer game. On the one hand, there is the "Massively Multiplayer Online" part which means that a large number of players can interact with each other through online means. On the other hand, we have the "Role-playing Game". Similar to classical role-playing games, a player controls a character set in a world, most of the times a fictional world, and through their character they can experience the world and interact in it. Although most games in that genre highly differ from each other, they still share the same features at core. We can break these down into three main categories.

### 2.1.1 The Character

First, there is the player projected into a world through an avatar or character and assuming the role of that character. Similar to traditional role-playing games, the player's character progression is the main goal of an MMORPG. Making them stronger by overcoming challenges, giving them better equipment, accumulating wealth are some examples of character progression in most MMORPGs. The player may also role-play their character and act in the world as their character would with some games giving more functionality and features to that end than others. The character is the player's gateway into the world the game presents as they take part in the content and activities inside this world.

### 2.1.2 The World

The world is in short everything the game has to offer in terms of content and features and is often accompanied by a theme. The most MMORPGs employ classic fantasy themes similar to the *Dungeons & Dragons* universe. Other themes might draw inspiration from science-fiction, already established franchises or other genres. The world is what gives the players content to engage with and immerse themselves into. In contrast

to single player role-playing games, the game's world persists and keeps developing regardless of if the player is online or not. The world provides challenges the player has to conquer and also a place for the player to interact and play with other players. It puts down the rules and boundaries on how this (fictional) reality works which the player has to follow.

### 2.1.3 The Community

Now to make an MMORPG "massively online" a lot of other players will roam the world simultaneously alongside the player. They can interact with each other, role-play together, form groups to face challenges or just experience the world together. Some games offer or even thrive at on the players opportunities to test their skills against each other in player vs player competitions. The more common aspect is for players to band together and fight against a strong foe as a group. All players combined form the game's community from which sub-communities also emerge which can unite in smaller permanent groups and gain some sense of belongingness or recognition.

## 2.2 A Good Game Experience

When discussing what makes a good game or what makes a good game experience, most game developers or researchers will have different opinions and answers to that question. This outcome makes sense considering a human experience is an abstract and subjective concept and thus difficult to quantify.

### 2.2.1 Approaches

As Schell [Sch08] states in *The Art of Game Design: A Book of Lenses*, the game is just a tool to induce a human experience inside the player. The game itself is not the experience. It is just an "artifact" since without a player the game means nothing as its sole purpose is to create a meaningful experience which cannot occur without a player experiencing it. On top of that, a game designer will never truly witness the outcome of their game because ultimately the outcome is an experience lived through a player and human experiences are in this day and age unsharable. The only examinable experience is the one each one of us experiences themselves which only helps to some extent as the experiences can widely differ from each other. Plus, different aspects of a game can provoke different variations of game experiences which also depends on the individuals previous experiences [Tak+10].
With that in mind, a game can be defined as good if it elicits an experience out of a player which is meaningful to them. In a broader sense, a game is good if the majority

of players experienc something meaningful out of the game which is often also coupled with a mixture of mainly positive emotions. So in order to answer the question of what makes a good game experience, we need to look into what influences and reasons make a game induce a meaningful experience which in turn by definition makes the game itself good.
Prensky [Pre01] proposes twelve different elements on what makes games engaging:

1. Games are a form of fun and thus enjoyable.
2. Games are a form of play and make the player feel involved.
3. Games have rules which gives structure.
4. Games have goals which gives motivation.
5. Games are interactive.
6. Games are adaptive which gives us flow.
7. Games have outcomes and feedback which lets the player learn.
8. Games have win states which gives us gratification.
9. Games have challenge or conflict which gives us adrenaline.
10. Games have problem solving which sparks creativity.
11. Games have social interactions which gives us social groups.
12. Games have representation and story which invokes emotions.

In short, compared to other entertainment media games are an interactive experience. They are mainly fun to play, have rules and goals and Schell [Sch08] presents a vast amount of features that a game contains and a variety of angles from which to look onto a game to possibly improve it. One key thing to note is that Schell puts a very big emphasis on the players themselves and that a game developer needs to understand how the player's mind works in order to make a great game. This means understanding different motivations, realizing what game mechanics are fun for the player and how to hone your thinking in a way to engineer a good game experience for the player.
Malone [Mal81] on the other hand proposes three different aspects to make a game intrinsically motivating or fun. Intrinsic motivation is when a person does something out of their own volition without outside influence. Getting paid to play a game, also called extrinsic motivation, stems from a different type of motivation than playing a game for personal enjoyment. His paper suggests that there are 4 factors which make games intrinsically motivating: Challenge, Fantasy, Curiosity and Control. These 4 factors have also been identified as key reasons to motivate people to play a game [HWW09].

Challenge measures the achievability of goals in the game relative to the difficulty of reaching that goal, for example the difficulty of defeating a boss to get better equipment for their character. Fantasy expresses the mental image that the player has not experienced before and thus uses the player's imagination to better immerse them into a world outside of own their experience. In MMORPGs, this notion is well-used since developers create non-player characters (NPC), enemies, environments, cultures and more for the game's world in which the player resides. Curiosity is split into sensory and cognitive curiosity. Sensory curiosity includes sensory information like sound or graphics that enrich the sensory experience. Cognitive curiosity refers to the user's lack of complete knowledge of the game's world and in turn increases player motivation to explore. Lastly, control discusses the amount of options or tools the player has in the game to interact. High levels of control signify a player who is highly skilled in the tool sets of the game and hence have a higher feeling of freedom in what they are doing in the game or in achieving more difficult goals. [HWW09] [Mal81]
Takatalo, Häkkinen, Kaistinen et al. [Tak+10] present the idea of a game experience being a combination of the game system and the player's psychology which together form the interactions between the player and the game. The game system provides rules, mechanics, world etc. for the user to utilize and to play with the system which in turn generates emotions. Vice versa, the player's perception, motivation or past experiences compels the player to interact with the game system through decision-making or challenges and in turn uses the game system's provided tools to do so. The game system is where the game developer can influence the play and emotions of the player and thus ultimately influence the game experience. In addition, this paper emphasizes the importance of presence, involvement and flow in digital games for driving factors in user experiences.
Bostan and Öğüt [BÖ09] summarize the game experience as an "activity of selective attention and a psychological process" and the enjoyment of the game stems from the complexity of "filtering and organizing artificial sensory information of the virtual world". The core of any kind of entertainment is a "complex construct with physiological, affective, and cognitive dimensions" However, they conclude in their study that enjoyment can be maximized through difficulty by optimizing game challenges and difficulty adjustments with regards to the player psychology. Difficulty is not the sole reason but a crucial part in achieving an optimal game experience. While making challenges achievable, believable and consistent, the player themselves should be considered when it comes to play style and player type.

### 2.2.2 Summary

From all the different definitions, common notions can be identified which will prove useful for this paper. The first thing to note is that the game itself is a means for the player to delve into a different reality, which in turn creates an experience by and for the player, while interacting and exploring the game using its system. The game system is what a developer can tune and optimize to potentially maximize the quality of the game experience. If the game is fun to play by nature, the player is more intrinsically motivated to play it and thus brings more joy to them. This can be influenced by creating appealing challenges, meaningful goals and implementing intuitive but intricate game mechanics to keep the player as engaged as possible. Finally, ultimately the player themselves is the key to a good game since it is their experience the developer wants to be meaningful. Thus, taking the player's psychology into consideration is essential in that regard, including player preferences, emotions and play style. To simplify the relations between the main elements of an MMORPG and the player, the following model is provided as a visualization for an MMORPG experience.

# 3 Flow

## 3.1 The Concept of Flow

Flow captures the mental state of one being fully absorbed, immersed and concentrated in an activity that the person is engaged with and attaining enjoyment while being in that state. The concept has been made popular by psychologist Mihaly Csikszentmihalyi in 1988 and has been researched ever since. Nakamura and Csikszentmihalyi [NC14] extensively describe the flow state and how it can be attained and influenced. Two key conditions have to be met in order to enter the flow state:

- Perceived challenges are adequately challenging in relation to the person's skills; The person in question feels that they are engaging challenges within their capacities
- The goals are clearly perceived to the person and the person gets immediate direct feedback in progressing towards them

As such, the person is able to enter the subjective flow state in which the following characteristics can be observed:

- Immense concentration on the task at hand
- Loss of awareness, a sense of full immersion
- A feeling of control, the person feels ready to tackle the situation and knows how to respond to what happens next
- Losing sense of time, typically the perceived time that has passed is more than the actual time that has passed
- Experience out of the activity in this state is intrinsically rewarding

In this state of immersion and control, perceived challenge and skill are in balance which can easily tip towards one or the other over time. If challenge begins to overpower the person's skill level, they become vigilant first and then anxious. If skill exceeds challenge, they first start to relax which will shift into boredom. Becoming bored or anxious compels the person to change the way they are handling the situation in an effort to regain the flow state.

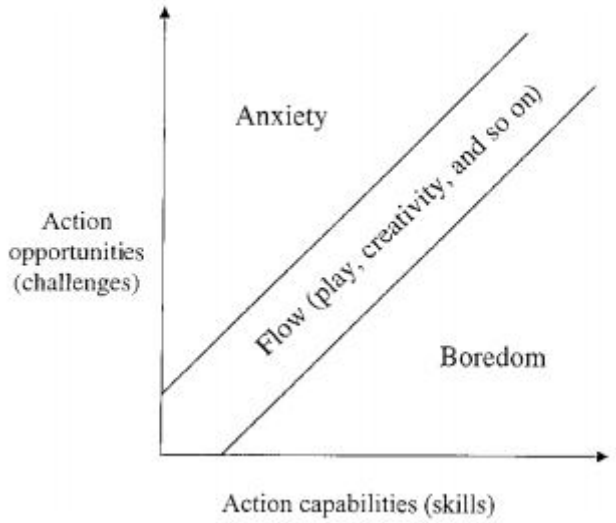


Figure 3.1: The original model of the flow state [NC14]

More recent studies however propose more granularity in emotional states and a modified definition of flow. Evidence supports that low challenges with low skill levels lead to a sub-optimal experience where the person will experience apathy and lack of attention which poses the opposite of the flow state. Flow is expected to occur when the person perceives challenges that are on average greater than their daily encounters with their skill levels. As such, the original flow model has been adapted to accommodate this finding. The current flow model can be seen in figure 3.2 with the middle denoting the person's average challenges in their daily life and skill level and the circles expressing the intensity of the experience.

Furthermore, supposedly the flow state is not the only state that is considered enjoyable. The Relaxation portion of the flow model also proves to be an enjoyable mental state with it having a low challenge but high skill ratio. The authors suggest that both the flow and relaxation state are intrinsically rewarding in their own regard; relaxation being the one to conserve energy and the other using skills to seize greater opportunities and challenges. This suggests that there is a preference between the two states depending on the person engaging an opportunity. Someone who deals more with high-stakes situations in their life might prefer a relaxed experience for a change whereas someone who does not have as much opportunities to show their skills may prefer environments which will foster flow. [NC14]

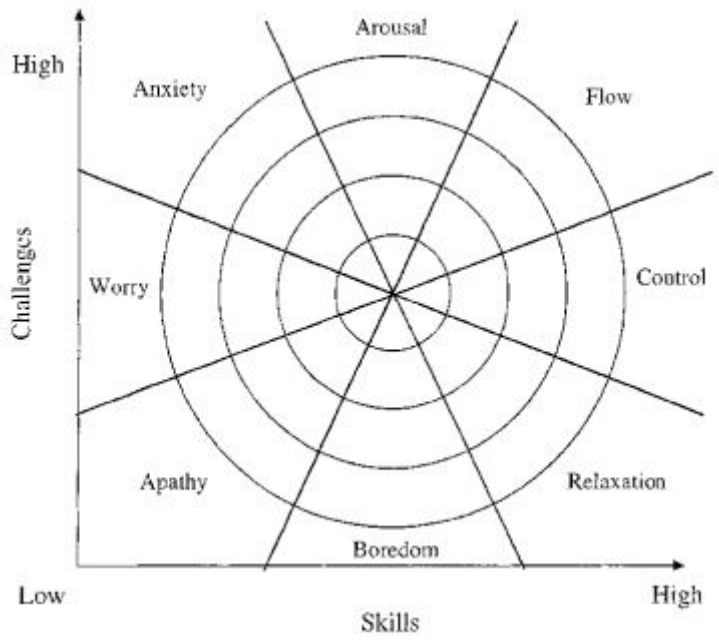


Figure 3.2: The current model of the flow state [NC14]

## 3.2 Influence on the Game Experience

### 3.2.1 GameFlow

The concept of flow can be directly applied to a game experience. Since games provide a regulated interactive environment with a goal involving problem-solving and decision-making, games are naturally prone to foster flow. That being so, Sweetser and Wyeth [SW05] created the GameFlow model which maps the elements of flow to game features.

A game needs to fulfill these flow requirements to maximize chances of the player entering the flow state and thus being fully immersed into the game. The aspect of social interaction is not included within the concept of flow but is considered a big contribution in improving a game experience and also a big factor in why players play a game especially in the context of an MMORPG. However, the GameFlow model only covers the flow state specifically and not the flow model. Since the flow model suggests two desirable states, namely flow and relaxation, the state of relaxation needs to be considered as well. For that purpose, I will use the GameFlow model to translate game features to the relaxation state with the following adjustments:

| Games Literature | Flow |
|---|---|
| The Game | A task that can be completed |
| Concentration | Ability to concentrate on the task |
| Challenge Player Skills | Perceived skills should match challenges and both must exceed a certain threshold |
| Control | Allowed to exercise a sense of control over actions |
| Clear goals | The task has clear goals |
| Feedback | The task provides immediate feedback |
| Immersion | Deep but effortless involvement, reduced concern for self and sense of time |
| Social Interaction | n/a |

Figure 3.3: GameFlow model [SW05]

- Concentration: The paper describes concentration as the game's ability to grab and hold the player's attention while providing adequate workload and stimuli within their mental capabilities. Since concentration is the opposite of relaxing, the game can lower the amount of workload and stimuli on the player appropriate to the low challenge, high skill ratio in the relaxation state. However, grabbing the player's attention through appealing stimuli does not have to be disregarded since it makes the game experience more captivating in general.
- Challenge: Similar to concentration, the game does not need to maximize challenge for the player since that is not the goal of relaxation. The game's challenges must not directly match the player's skill level in favor of less stakes for the player. Regardless, the game should appropriately increase challenge throughout the game proportional to the player's skill level to not fall into the boring or apathy states.
- Immersion: Immersion does not need to be present with regards to relaxation since immersion implies a deep emotional involvement with the game and can be burdening on the player if the game's concepts, themes or mechanics become hard to follow. However, immersion is a contributor in delivering a good game experience and if the game proves easy to immerse a player with, then immersion does not exclude the possibility of relaxation.

The rest of the GameFlow features can be left as is since these features can be unified under the relaxation state and are generally helpful in creating a good game experience. A game whose controls feel clunky or unresponsive or feedback and goals are vague

can become frustrating or an unpleasant game to play in general and does not involve flow at all.
In conclusion, both the flow or relaxation state can be used in order to use the flow concept to improve the game experience. It is up to the developer whether they want to only encourage flow or only relaxed states or a mix of both. The bigger issue here lies within the player preference as games will be played by both players who prefer being in the flow or in the relaxation state. This can be solved by carefully developing for a specific target audience or by tackling the main difference between the two states dynamically through adaptive difficulty.

## 3.3 Application in Adaptive Difficulty

With the purpose of achieving an optimal game experience, these concepts are fundamental as they pose a correlation between difficulty and skill to game experience. In an ideal world a game can determine the skill level of the player who is playing the game and perfectly adjust its mechanics, environment and difficulty accordingly to the player's desires. Compared to player vs player games where most games utilize a matchmaking system to find an opponent matching the player's skills to make a game fair, in an MMORPG in most of the cases the enemy is an artificial intelligence with a set difficulty.
However, after the flow concept this set difficulty will not appeal to every player. The most difficult task in creating an environment for flow or relaxation to thrive is to measure and adjust difficulty according to the current player's skill sets and levels. On top of that is the problem of that MMORPGs not only has to satisfy one player but multiple players at once. In an attempt to solve this issue, we will look into approaches and concepts of difficulty itself and adaptive difficulty.
Another aspect worth looking at is that adjusting difficulty is not the only parameter to create flow or relaxation. Player skill as the other parameter can also be utilized when looking to apply flow. If a player is incentivized or motivated enough to raise their skill to match the difficulty level presented to them, the flow objective gets shifted from "beating the difficulty" to "become good enough to beat this difficulty" or even "become good enough to master this difficulty". Depending on the design goal of the game, a game's difficulty must not be a necessary hurdle to get a player to enter flow, it can become a goal in itself which then moves the matter of difficulty to other features of the game than before. This, however, is still a matter of player preference as this is mainly an aspect to achieve the flow state specifically.

# 4 Difficulty

In the following chapter we will look into the two difficulty concepts that are most commonly used in video games: predetermined difficulty and adaptive difficulty. Both concepts are going to be useful in defining the term "optimal difficulty" which will be the main measurement in ultimately attaining an optimal game experience specifically in the MMORPG genre.

## 4.1 Predetermined Difficulty

Predetermined difficulty is the most commonly used form of difficulty as it is the easiest to implement for a developer. Difficulty in this case does not dynamically change while playing the game and the game does not measure the player's performance. It is simply the difficulty the developers have set out for the players to experience and to overcome. In the best case the laid out difficulty is appropriate for the player and they thoroughly enjoy the experience. It is more likely the case though that the player either thinks the game is too easy for their skills and gets bored, or too hard and quits the game after a few attempts.
However, most games do not offer just one difficulty and instead give the player the choice to choose between several difficulty options. More commonly the player gets to choose between an easy, intermediate or medium and hard difficulty. Regardless of choice, each of these difficulty levels are still predetermined difficulties estimated by the developer. The player will not know how difficult or easy these difficulty levels are beforehand since "easy" for example might be a hard difficulty for someone without the proper skill levels. A prominent example for this is the the original *Doom* [Sof93]. It offered five different difficulty levels from easiest to hardest: "I'm too young to die", "Hey, not too rough", "Hurt me plenty", "Ultra-violence" and "Nightmare!" with each either changing the number of enemies and power-ups, ammo rarity and damage taken by the player. Still, these implementations of difficulty are not transparent to the player when picking a difficulty level and they have to play the game at a difficulty level to experience how easy or hard it actually is.
More modern games offer a more customizable and transparent experience though by giving the player more options to choose from. More specific difficulty levels, detailed description of each difficulty level and making the difficulty levels themselves

customizable are examples of giving the player more power in adjusting the difficulty what they think is appropriate for them. A good example for that is the recent *The Last of Us 2* [Dog20]. At release, the game offered five different difficulty levels with each having a short description for whom this difficulty might be appropriate for and what that difficulty level entails. Additionally, the player can make their own difficulty by customizing it: Player resilience, aggressiveness of enemies, aggressiveness of allies, vigilance of enemies for stealth mechanics and rarity of resources. If the player is good at aiming a gun but is not as good at sneaking around the enemies, they might opt to increase enemy aggressiveness but lower their vigilance. In this regard, the player has plenty of control to adapt the game difficulty as they desire.

## 4.2 Adaptive Difficulty

Adaptive difficulty implementations on the other hand change the game's difficulty dynamically using information the system gets during game-play or beforehand. By measuring the player's performances through specific indicators, games with adaptive difficulty adjust the game's difficulty appropriately on their own, for instance through changing scenarios, parameters or entity behaviour. After Andrade et al. [And+05] it is suggested that adaptive difficulty needs to tend to the following points in games:

- The game needs to monitor the player's performance and abilities and adapt to it
- The game needs to follow the player's improving or decreasing skill levels and accordingly maintain a balance between difficulty and player skill
- The adaption itself does not need to be apparent to the player and game state transitions need to be reasonable with the adaptation

This already implies the two main difficulties of implementing adaptive difficulty. How does one quantify and measure a player's performance? If a difficulty adjustment is needed, how and where does one change the gameplay to accommodate the difficulty change? We will look at different approaches in the next two sections.

### 4.2.1 Measuring Player Performance

Measuring the player's skill level is important in order to determine where on the flow graph the player might be in at any given moment. Unlike player vs player formats where competition is an easy way to gauge performance or skill, other methods need to be utilized to measure performance against artificial enemies.
One option is to measure the player themselves. Through questionnaires a player profile can be created with which the system can better adjust the difficulty according to their

preferences [Yun+10] [Cha+05]. Complemented with player performance (which we will look into later), the player profiles can be adjusted and reevaluated and thus create a feedback loop with the player profiles, performance and difficulty changes [Cha+05]. Another choice is to assess emotions the player experiences during gameplay. By actively measuring the current emotional state or position in the flow model, changes can be made accordingly. The issue with his method lies in practicability and accuracy since the player needs to be equipped with sensors in order to guess the player's emotional state [Cha+08].
A more modern and complex approach includes machine learning and neural networks. The AI observes the player behaviour and tries to guess the player's next moves and act depending on the desired behaviour or user skill level [And+05][PSM20]. The information gets fed into a neural network and each decision of the agent gets a weighted probability depending on what the best action is in the current situation. However, if the agent is trained during game-play and not from existing data beforehand, the agent will have difficulties playing against good players at the start because it is not yet trained. Additionally, it may lead to unrealistic behaviour in a given context [Zoh18]. With that said, using machine learning has proven to be a successful way in improving intrinsic motivation and providing unique experiences by making the enemies adapt to and mirror player behaviour [PSM20].
The most common approach to measuring player performance is through heuristics and examining the current game state. By observing game play metrics like health points of the player's character or, numbers of victories or time, the game can use these indicators for performance in order to determine the need of difficulty adjustments [And+05] [HJ09]. A good example for this is the *Hamlet System* in the *Half Life* game engine [Hun05]. By measuring the damage the player takes over time and their inventory, the system determines whether adjustments to the game are necessary. The system tries to predict when the player repeatedly cannot reach a game state with their current means and helps out in that case. If the player performs well, the system might also switch to a harder mode where the average health of the player is held low and resources are more scarce.

### 4.2.2 Applying Difficulty Changes

After it is determined that difficulty adjustments are needed, applying difficulty changes can be done in countless ways depending on how the developer wants to impact or alter the experience. There are small changes from changing health or attack numbers to more impactful changes like spawning items [Hun05] or NPCs [AM10] to help or disrupt the player, giving or taking resources, changing game mechanics or user

interfaces [LC04], changing the environment or altering the AI [Hun05]. As there is no recipe in making a "correct" adjustment in difficulty since each change can widely impact the game experience, policies and executions for adjustments must be considered carefully and always with the players in mind.
Denisova and Cairns [DC15] propose that even a small adaptation based on player performance can improve game experiences. According to their study, players needed to score as much points as possible on a timer in a small shooting game. The speed at which the timer decreased was changed based on how many points the player was achieving on average. The participants "felt more immersed" and believed that they gained their results all in the same amount of time which consequently means that all players felt that they had the same perceived challenge. More skilled players wanted to get the highest score possible and less skilled players found that achieving the needed amount of points was difficult enough.
However, they also suggest in another study [DC19] that the game experience also heavily depend on the player's expectations going into the game. In this case specifically, they found out that player immersion is improved when they were informed that adaptive difficulty adjustments were present when playing regardless of whether they were actually present or not. According to that study, players were more immersed the more details they knew about the implemented adaptation. The expectation of having a considered positive game feature in the game is sufficient to increase the player's immersion.

## 4.3 Optimal Difficulty

Optimal, after the *Oxford English Dictionary*, means "the best possible; producing the best possible results". From a difficulty standpoint, optimal difficulty can be defined as difficulty that is comfortable or challenging for most if not all players and thus providing a good game experience. With adaptive difficulty, the difficulty can be adjusted appropriately and personalized to a player if well implemented with measuring the player's performance and player preference to some extent. However, giving the player the choice to personalize their experience themselves can make for a good baseline to adjust difficulty from since only the player themselves know how challenging they want their game to be. Naturally, the more information the system can gather from the player preferences and skills the more precise the game can pinpoint the optimal difficulty for that player.
Ultimately though, it is important to note that in order to make an optimal game experience with optimal difficulty, we do not particularly seek to be in the flow or relaxation state but rather avoid the boredom or apathy state. In the best case the player

enters the flow state and stays there for the majority of their playtime but entering the other positive states still provides a good game experience. Keeping the player engaged and not lose their interest through boredom or apathy is the main key in making an optimal game experience and thus appealing to all players. Consequently with optimal difficulty in mind, creating challenges that are fun and engaging with regards to the player's skill level is more important than the difficulty of the task itself.
For example, take a Jump'n'Run game where you have to reach a goal in a certain amount of time. Player A is a player who is proficient in Jump'n'Run games, Player B is someone who rarely plays these games. As the challenge is to reach the goal before the timer runs out, player A might find themselves in the flow or relaxation state. If the timer is relatively short, player A could struggle in reaching the goal in time and needs to concentrate in order to beat it and thus possibly enter the flow state. Player B, however, is likely to be anxious since they can't reach the goal in time as it way too difficult for their proficiency at Jump'n'Run games and will seemingly quit the game. If the timer is long, player A has more than enough time to reach the goal in time and so enjoys the game at lower stakes while having full control (because of high skill levels). Player B on the other hand will most likely feel apathetic towards the game as it has no purpose for them since the game provides no challenge despite their low skills in such games.
In the end, if the player does not require any skills to fulfill a task, then the difficulty arguably does not matter after the flow model. However, if they do, then the difficulty can be adjusted to provide a more meaningful experience through the flow state.

### 4.3.1 Difficulty in the context of an MMORPG

In the context of an MMORPG, difficulty needs to be put into perspective since challenges in an MMORPG means rewards. In a persistent online world with a big community, social factors are a big contributor to why people play MMORPGs as seen in Fig. 2.1. Rewards from challenges in the game gain value among the community depending on the difficulty to obtain them. As a consequence, if difficulty gets dynamically adjusted in a challenge in an MMORPG, the reward has to be adjusted appropriately as well or the challenge itself loses its incentive. If this challenge gets adjusted to be easier but the reward stays the same, that would be unfair towards players who did not get that adjustment but the same rewards. Same thing happens when the challenge becomes harder, the players with higher skill levels have to do a harder challenge for the same rewards. Exploitation also has to be taken into account because if there is a system in place to adjust the difficulty for a set reward, players will take advantage of the system and intentionally make the challenge easier to get the reward.

Additionally, optimal difficulty now has to also apply for multiple players at once rather than single players. Since it is common to group up in MMORPGs to tackle challenges together, the experience for each player has to be enjoyable for everyone while the game cannot adjust the difficulty for each player individually through adaptive difficulty. This can be solved by multiple ways: find an average difficulty level to make it as enjoyable for everyone as possible, increase incentives like rewards, make the adaptive difficulty system a goal in itself or leave the difficulty up to the player to decide (using predetermined difficulties). Reaching higher difficulties with an adaptive difficulty system by improving skill levels can become a goal in itself with promise of higher rewards at higher difficulties.
Before attempting to implement an adaptive system into an MMORPG environment however, variables for measuring player performance need to be identified which I will analyze through a boss fight in *Final Fantasy XIV*.

# 5 Parameters for Difficulty Adjustments

To evaluate the performance of all the players in a group, a foundation needs to be laid down for this purpose. The best way to gauge skill level of the group in a specific environment is by directly extracting information while they play and determine how they perform during game-play. Therefore, I examine a boss fight in *Final Fantasy XIV* [Eni10] as an example to find variables from which to extract information and make it applicable for MMORPGs in general.

## 5.1 Investigation

The boss fight I have chosen to investigate is the *The Navel (Extreme)* fight. 8 players (with some exceptions) enter a specific arena to fight an enemy. The fight has 3 different difficulties (normal, hard and extreme) from easiest to hardest. I have chosen the hardest difficulty since it provides the most information and most mechanics to showcase.

### 5.1.1 Basic information

The boss in this case is called *Titan*. The arena for this is a circle-shaped arena with walls on the edge. The players enter this fight as 3 different roles: 2 tanks, 2 healers and 4 damage dealers. Tanks are specialized in defense and are tasked to keep the boss' attention so that the boss does not go after the more vulnerable party members. Healers are responsible for keeping the group alive through healing. Damage dealers have the task of dealing as much damage as possible to defeat the boss. The fight is won once the boss' health points reach zero. If all players die during the encounter, it gets restarted and the fight starts from the beginning again.
The encounter can be split into four different parts called *"phases"*. Each phase gets triggered if certain conditions are met, like a health points threshold, and has different *mechanics*. Mechanics in this context are attack patterns or game mechanics specific to this boss fight that need to be avoided or handled properly or else individual players or the party suffers penalties like damage to their health points or dealing less damage. I will only look at the first two phases for the purpose of the scope of this investigation.

### 5.1.2 Encounter Phase 1

This phase starts as soon as the encounter begins. The boss cycles through four different attacks each with a specific delay in between.

1. *Landslide*: A random player gets targeted with an attack that hits in a rectangular area from the boss through the targeted player to the end of the arena. After a short delay, any player standing in that area gets damaged and significantly pushed back.
2. *Weight of the Land*: Each player gets directed with a circular attack directly under them. If a player stands in any of the attacks after a short delay, they take damage.
3. *Mountain Buster*: The boss aims for the player who has its attention right now with a cone-shaped attack. Everyone standing in the cone gets hit with severe damage and a stacking penalty with each penalty increasing the damage the player takes from the boss.
4. *Tumult*: Every player takes moderate unavoidable damage.

The boss repeats this phase pattern until it reaches 90% health points. Once the health points are at 90% or below, the fight transitions over to phase 2 with:

5. *Geocrush*: Every player suffers more damage the closer they are to the middle of the arena and the walls of the arena get removed. The arena also becomes smaller. Players who walk or get pushed off the arena now will instantly die.

### 5.1.3 Encounter Phase 2

After Geocrush, phase 2 begins:

1. *3-Way-Landslide*: Same as the original Landslide, it targets a random player with a rectangular attack. However, 2 additional Landslides appear with this Landslide 60 degrees to the left and right of that Landslide each affecting the players in the same way.
2. *Gaols*: 2 random players become trapped and are unable to do any actions or move for the duration. The other players need to attack the trap until it reaches zero health points or the trapped players will die after a certain amount of time. During the time the players have to free the players, a Mountain Buster, Upheaval and a 3-Way-Landslide occur one after another.
    a) *Mountain Buster*: This works the same as in phase 1.

b) *Upheaval*: The boss charges an attack that pushes the players 3/4 of the current arena size in distance originating from the boss.

c) *3-Way-Landslide*: This also happens the same way as in the start of phase 2.

If the 2 trapped players are not freed by now, they die.

3. The next 4 attacks are Tumult, Weight of the Land, Mountain Buster and a 3-Way-Landslide. They work the same as before.

4. *Bomb Boulders*: Explosive boulders are going to fill 2/3 of the arena with the other 1/3 being safe. Any player standing near the bombs will without help die.

5. Another 3-Way-Landslide follows. After that resolves, the Bomb Boulders will now explode. Finally, following another Mountain Buster, phase 2 starts to loop.

The encounter transitions to phase 3 as soon as the boss hits 55% health points with another Geocrush making the arena even smaller.
Every attack has a visual indicator before it occurs for the player to react to except for Mountain Buster and Tumult, either by a visual marker or by the boss or mechanic itself. Using this timeline of events, I extracted parameters from which to measure player performance and possibly apply difficulty changes.

## 5.2 Results

As this is only one example out of one MMORPG game, it is necessary to abstract the information and make it more generally applicable. Thus, the following information can be found through this fight:

- A group of players enter the encounter with varying progression states and skill levels
- The enemy/enemies must be defeated together by overcoming game mechanics and through mastering their character's abilities and skills
- A general timeline dictates what happens in the encounter through time or other conditions
- Encounter specific game mechanics and enemy behaviour make the fights unique and different from each other
- Simple adjustments like changing health or damage numbers can be an easy way to make subtle difficulty adjustments

| Parameter | Description | Measurements | Adjustments |
|---|---|---|---|
| **Time** | Anything that pertains time in the overall encounter structure | Encounter time | Max. time given to the players, time for certain phases, Mechanic timings |
| **Attempts** | Data of current and previous encounters | Total number of attempts with this encounter, unsuccessful/successful previous attempts | Maximum number of attempts |
| **Enemy** | Enemy features and anything that directly involves the enemy | Damage dealt without mechanics, Damage received, Hit frequency by players | Health points, Statistics, Hitbox, Number of enemies, Targeting, Behaviour/AI |
| **Players** | Player features of a player and skill level | Equipment, Progression, Statistics, Actions per minute, Damage dealt/received, Number of Players | Raising/Decreasing player stats, Bonuses/Penalties, Number of players, Player restrictions |
| **Mechanics** | Attack patterns or game mechanics that players have to overcome or deal with | Number of successful/unsuccessful executions for each player, Time needed for successful execution, Damage dealt | Frequency, Obscurity/Clarity, Time to react, Geometry, Adding new/Omit mechanics, Combining/Separating mechanics, Targeting, Penalties for failing/Bonuses for succeeding |
| **Environment** | Anything involving the surroundings and arena of the encounter | N/A | Size of arena, Obstacles/Advantages, Special areas (e.g. do-not-enter zones, beneficial zones) |

Table 5.1: Parameters for measurements and difficulty adjustments

- More intricate adjustments can be targeted mainly at the game mechanics, enemy behaviour and/or the environment/arena

As an example for this fight, if we change the enemy health points to be lower from the start, the players would see less game mechanics as the fight is overall shorter and thus easier to complete. Moreover, adding or leaving out game mechanics or even a whole phase would immensely influence the overall pacing and difficulty of the fight. If we add some pillars in the arena to stand behind to make Landslide avoidable, that would make that specific game mechanic much easier to avoid and overcome leaving more room for dealing damage to the boss. In short, any adjustment made to any parameter can influence other parameters and impact the overall encounter by a considerable amount. I grouped and laid out the parameters I discovered for measuring player performance and difficulty adjustment applications in Table 5.1. In the following chapter, using these findings I will showcase a simple adaptive difficulty system in a multiplayer RPG setting in order to simulate an MMORPG encounter.

# 6 Implementing Adaptive Difficulty

## 6.1 Game Description

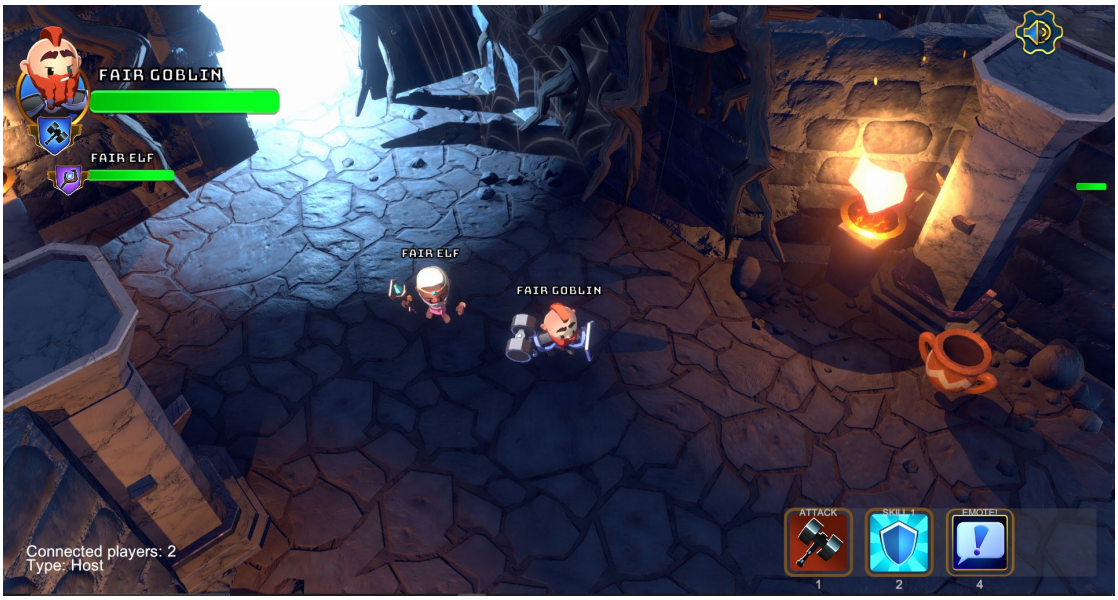


Figure 6.1: Boss Room entrance [Uni21]

The project used for this purpose is the Unity open-source project called *Boss Room* [Uni21] for PC. It is a cooperative multiplayer RPG project for 1-8 players featuring 4 different classes and a fully playable dungeon. Each class has a basic attack and 1-2 unique skills depending on the class. The players enter a dungeon filled with imps and an imp boss at the end of the dungeon. The task of this game is to fight through the dungeon and defeat the imp boss. Throughout the dungeon are imp portals from which imps will regularly emerge which can be deactivated by destroying the crystals in front of the portal. Once the players reach the boss room, they will have to fight the imp boss. The imp boss has a basic melee attack and a charging attack. During the charging attack the boss will take a few seconds to prepare before charging forward and damaging players in the way. However, this attack can be dodged or strategically

aimed at one of the pillars scattered through the boss room. If the boss charges into a pillar, the boss gets stunned for a couple seconds unable to execute any actions and destroying the pillar. The players win if they defeat the imp boss and they lose if all players die.

## 6.2 Approach

The goal of this prototype is to create an environment in which difficulty gets adjusted depending on the group's overall skill level to improve the game experience through flow. Since difficulty needs to be as appropriate as possible for multiple people at once, making adjustments for individual players while still maintaining the overall balance of the game is too complex for this endeavor. Subsequently, information on the group as a whole is needed. However, unlike ongoing MMORPGs which have data on their players, this project is fairly new (released April 2021) and for educational purposes and thus has no player data from which to extract information. Therefore, information about the group's performance and perceived difficulty must be determined as best as possible from in-game data. For this purpose, I used the previous created table 5.1 to gain information about the players and adjust difficulty accordingly. Hence, I attempted to cover each point in that table and will discuss the effectiveness and results in the following chapter.
As this game was originally designed only to be a small cooperative RPG, winning or losing this game ultimately has no effect outside of it whereas in an MMORPG it needs to have some kind of reward to make it appealing to play. If it does not have a reward for the player for completing this game and it was part of an MMORPG, the player would have no reason to do it since it does not help progress their character nor provide a form of achievement for finishing it. For that reason, either some sort of player feedback or reward system needs to be implemented in order to make it appealing for an MMORPG environment.
Finally, *Boss Room* as a game itself is rudimentary in game mechanics and the interest curve is rather flat meaning that the challenges posed for the players are static and do not change over time. This serves the purpose of making the game experience in general more exciting and appealing to the player. Plus, this provides another opportunity to make difficulty adjustments.

## 6.3 Implementations

The first modification to the game is making the boss' strength scale in strength over time. This serves to subtly increase the challenge for the players and make the

experience more dynamic. The increase happens in set intervals starting from when the boss was engaged. The faster the players take down the boss the easier it is for them to do so as it will get stronger over time.
As this game is available for 1-8 players, to beat the game as 1 player seems impossible and playing the game as 8 player is not a challenge at all. Therefore, the enemies health scale should depend on how many players are in the current group. This is a straight-forward solution in making the game's difficulty scale with the amount of strength the players have.
In addition, for the reason that this game would need some sort of a reward system or player feedback in an MMORPG environment, a basic scoring system is implemented. Each killed enemy and a win gives you points. Usually MMORPGs provide rewards in form of character progression or achievements but since this game was not designed to be part in an MMORPG, a scoring system will suffice in gauging the amount of rewards the players would get in value. At the end of each round in the dungeon, the score, current difficulty level and number of players are noted in a text file in the game's folder.
Now, the adaptive difficulty system uses in-game metrics to approximate the current players performance. For that, the system has an internal difficulty level the players are on currently. The difficulty level gets increased or decreased depending on how many times this session the players have won or lost the encounter. For each win the level increases, for each loss the level decreases. The level of difficulty dictates how much harder or easier the game is set right now from its normal predetermined difficulty and is the main metric in adjusting the difficulty. For each level in difficulty, the following changes will happen:

- The interval in which the strength of the boss increases
- The amount of points
- The damage the imps deal

The higher the difficulty the smaller the interval for the strength increase is, the more points the players get and the more damage the imps deal and vice versa with lower difficulty levels. However, adjustments towards the lower end are capped at some point since otherwise the enemies would eventually deal no damage or the players would get no points at all which is not the purpose of this system. Finally, the system tracks how many times the charging attack of the boss successfully hits a player or not. If the players get hit too often by that attack then that might indicate that it is too hard to avoid or handle for the players. Therefore, the system will create more pillars to provide more opportunities for the boss to run into and ultimately making that mechanic easier to deal with.

## 6.4 Results

Overall, albeit the fact that the adjustments are elementary, they prove effective in making the experience more dynamic and optimal. Following points from Table 5.1 have been utilized to make difficulty changes:

- **Attempts:** Number of attempts - Wins or Losses
- **Players:** Player count
- **Mechanics:** Unsuccessful executions - Amount of hit charging attacks
- **Time:** Mechanic timings - Interval of boss' strength increase
- **Enemy:** Health points and strength
- **Environment:** Advantages - Adding pillars to hide behind

The first 3 points depict the measurements used to determine the need of difficulty changes while the last 3 are the concrete difficulty adjustments made to increase or decrease challenge. Despite them being separate parameters, they are all related and influencing each other. For example, the environment is used to make the charging attack mechanic easier, enemy health points and strength influence the amount of times the boss becomes stronger and a higher player count entails higher chances of getting hit by the charging attack which in turn warrants difficulty changes.
Compared to the unmodified version of the game, the changes seem to create an overall better experience for the players. It is now more feasible for a single player to beat the game and it poses more of a challenge for bigger groups. More skilled groups might enjoy a bigger challenge and more inexperienced players possibly will welcome an easier encounter. Ultimately, the goal is to create an optimal experience for all players and building a more dynamic and engaging encounter would serve that purpose.

# 7 Discussion

## 7.1 Effectiveness of Adaptive Difficulty towards the game experience

As seen by the implementations done in the chapter before, changing the difficulty dynamically can drastically alter the game experience for each individual player. The flow model is a vital concept in creating an optimal experience and thus making the difficulty adapt to the player's skills and preferences is one solution for that task. Plus, the system's accuracy in evaluating appropriate adjustments can be fine-tuned the more information it attains. By putting in place more complex examination systems of the player performance or behaviour or gaining data on player preference, skill or play style, concrete changes can be tweaked and molded more carefully towards the player's desires. Finally, adaptive difficulty opens the possibility of removing a "hardest" and "easiest" difficulty. By making the difficulty dynamic, the difficulty could rise beyond what was before considered the hardest difficulty and also go lower than the easiest difficulty if needed. Dynamic difficulty possibly entails more granular difficulty levels which is another advantage of this concept.
However, as established before, the game itself is only a tool to create a game experience. The best way to determine what kind of game experiences it produces, players need to test the game and judge for themselves. Fundamentally, a game experience is heavily dependent on human psychology and therefore complicated to quantify. Compared to other media like movies or books, games are interactive in nature and so creating an optimal experience for a consumer who has to some extent control over their experience makes it even more intricate and complex to pin down. An adaptive difficulty system, however, is one effective measure towards that goal. Table 5.1 might prove useful as a foundation in implementing such a system but making conclusive difficulty adjustments are game specific because different game mechanics and features each require different balance changes.
Nevertheless, difficulty is but one out of many facets of a game experience. As seen in Figure 2.1, challenge is just one out of 5 variables what makes the game world of an MMORPG interesting. A well-implemented dynamic difficulty system can improve the game experience for a broader audience who would not have enjoyed it on a static

difficulty setting. But, a game with clunky controls, convoluted interfaces or a boring narrative can only be balanced out so much with perfectly adapting the difficulty. Such a system can enhance the experience but is not an universal solution for other issues a game might have.

## 7.2 Customization vs Automation

An ideal dynamic difficulty system would be able to exactly determine what kind of experience in regards to challenge the player wants and make perfect adjustments in the game. However, as games are unique from each other, such an universal system might never exist. Thus, as of now only approximations and estimations can be made which might lead to a better experience but could also lead to a worse experience than a game with a static difficulty. This, again, is heavily dependent on the player's preferences and perceptions which makes solving this issue so complex. Consequently, this leads to the question whether a system or the player should decide what is best for the player's experience. On the one hand, the system has knowledge over its whole game and can fine-tune features given it has information on the player. Without full information on the player however, the system might make wrong changes and worsen the game experience in the end for the player. On the other hand, the player knows their preferences the best and what they want out of the game but lacks the information on what a specific difficulty setting entails. They might be eager to beat a game on a harder difficulty but ultimately fail which leads to a bad game experience and might have been prevented if a system decided the difficulty level.
The answer to this question lies in the goal of games and what an optimal game experience is. Games are tools to create experiences and an optimal game experience is the best possible experience for the most amount of people. The more *accessible* and *fun* a game is for the majority of people, the better a game is serving its purpose. If an adaptive difficulty system is not creating the experience a player wants out of the game, then giving them the choice to make adjustments themselves would be the better option. Until there is a system which can perfectly tailor the game's difficulty to every players desire, the player should have the option to opt out of the dynamic changes since there is the possibility that the system could worsen the experience.

## 7.3 Impact of an Adaptive Difficulty system in an MMORPG

As explained in 4.3.1, difficulty is not as straight-forward in MMORPGs as it is for most other genres. To beat a difficulty in MMORPGs is more often than not a goal in itself since it provides rare rewards and also some sort of prestige. Moreover, adjusting

difficulty for multiple people at once is even more complex and difficult than it is for one player at a time.
With that said, these kinds of systems can still prove useful in MMORPGs if implemented correctly. As of now, in most MMORPGs difficult content is not accessible for more casual or less skilled players as they are simply too difficult or complex for them to complete them. With optimal experience in mind however, an opt-in adaptive difficulty system could make these types of content accessible to those players with cost of the original reward gained from them. More players are now able to enjoy this type of content and player's who have completed it on the original difficulty are not treated unfairly as the reward is less or not existent in the adapted difficulty version. Moreover, content that has to be completed for the sake of progression or story could be adapted as well in case a player struggles to complete them if there is no prestigious reward barred behind it. That way they do not get stuck at a certain point unable to progress at all halting the game experience. Giving the choice to the player is important though whether they want adaptation or not since some might welcome a lower difficulty whereas others might want more attempts at the challenge and overcome it by simply improving their skills. Another application might be to make a dynamic difficulty system the goal itself. Dependent on how high the difficulty gets adapted to the higher the rewards are the players get. In this concept, every kind of player gets rewarded appropriately, has an experience with a difficulty comfortable to their skill levels and it provides an incentive to strive for more challenge.
Regardless of specific application of an adaptive difficulty system in an MMORPG, they have to be put into context with the community aspect of the game. If it would treat some players unfairly compared to other players then such a system would impair the game experience overall. If it serves to make some type of content more accessible to more players regardless of skill level and with others players in mind, then a dynamic difficulty system could be adopted into an MMORPG.

# 8 Conclusion

An adaptive difficulty system can be an efficient way to optimize the game experience for a broader audience of players. Using the concept of flow, these systems or developers can gauge where on the flow diagram a player might be in right now and what kind of adjustments the game needs in terms of difficulty if needed. In the context of an MMORPG, dynamic difficulty systems can be implemented in some places for the sake of accessibility but the community and having to measure multiple players at once at times has to be considered. Using an example encounter from *Final Fantasy XIV*, I have created a baseline from which one could implement such a system into these types of encounters which are common in the MMORPG genre. The more accurate a system can determine a player's perfect difficulty level through information on them the better it can improve the game experience in terms of difficulty. Ultimately, the goal of a game is to create an optimal experience which is dependent on the player and until there is a system which can accurately tailor the difficulty for all kinds of players, it is best to leave it up to the player to decide whether they want adaptation or not.

## 8.1 Future Work

More testing and verifying can be done on Table 5.1 to find out how applicable it is on other MMORPGs and how useful it is in implementing such a system in an MMORPG. By further extending and improving on the concept it might illustrate a better general baseline in creating a dynamic difficulty system for MMORPGs and other genres. In addition, the system implemented in the prototype here can also be further analyzed and improved on to extract more useful information in order to increasing the accuracy and effectiveness of it. Making different adjustments, measuring player performance from different variables or an entirely different implementation approach could yield interesting results.
Adaptive difficulty systems are an interesting topic in game design as difficulty is one of the many aspects that needs to be done right in order for a game to be good for a broad audience. Therefore, research on different implementation approaches like reinforcement-learning or neural networks in order to more accurately measure the player's performance is vital in possibly creating a better system. Furthermore, as game experiences are a matter of human psychology, research on analyzing human

reactions and emotions and how to capture and measure them might prove useful to improve adaptive difficulty systems. The more information the developer can feed into the system the more accurately it can make adjustments that fit the player's needs.
Lastly, more research on the nature of game experiences and flow can also be conducted for the purpose of further making the experience optimal. By better understanding the relation between difficulty, skill and experience the better a developer can create a game that creates an experience that appeals to more players. Interdisciplinary research among other media or other game genres could result in useful insights on this matter as well.

# List of Figures

# List of Tables

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